Chapter 3

3.3 HYDROLOGY

3.3.1 Introduction

This section discusses the direct and indirect effects of forest practices on the hydrology of state and private forestlands. The primary emphasis of this section is on peak flows because peak flows can accelerate bank erosion, change channel morphology, degrade water quality, and cause downstream flooding. Peak flows, which can become large floods, can adversely affect aquatic habitat, water quality, public infrastructure, and public safety. Timber harvest activities can affect runoff through two main mechanisms, increased runoff due to timber harvest and increased runoff due to roads.

3.3.2 Affected Environment

Three primary processes affect the hydrologic function of forested watersheds.

1. Precipitation and surface/subsurface water flow regimes determine the rates of delivery of water to forests. These processes are largely controlled by climate.
2. Interception, condensation, evapotranspiration, and canopy snowmelt determine delivery of water to the forest floor. These processes are controlled mainly by vegetation.
3. Surface and sub-surface pathways transport run-off from the forest floor to the streams. These pathways are controlled by the interaction of condensation, precipitation, evapotranspiration, interception, snowmelt, and other physical and biological factors.

The hydrologic functions of a watershed are dependent upon these processes. When these processes are individually or cumulatively altered by road construction, harvesting, or other forest practices, the hydrologic continuity of the watershed is altered. Three major areas of hydrologic concern (annual water yields, low flows, and peak flows) are discussed in this section. Section 3.3.2.4 describes how forest practices have affected hydrology.

3.3.2.1 Water Yield (Annual)

Water yield is the amount of water that enters the stream system in the watershed. Various studies (Helvey, 1980; Bosch and Hewlett, 1982; Harr, 1983; Kattlemann et al., 1983; Troendle, 1983; King and Tennyson, 1984; Trimble and Weirich, 1987; Keppeler and Ziemer, 1990) have shown increases in water yields from timber harvest. However, the increase in water yield is usually beneficial to the aquatic system (unless it results in peak flows - see below) and will not be addressed in this section.

3.3.2.2 Low Flows

Low flows are often referred to as baseflows, dry-weather flows, and groundwater flows depending on the specific need. Low flows are the flows provided by groundwater to the streams during the lowest precipitation months of the year in the summer. In western Oregon, increases in low flow are generally short-term (5 years) following clear-cut timber harvest (Rothacher, 1970; Herr et al., 1982). In a northern California study, summer low flows were increased following selection harvest and then declined irregularly for 5 years until they were indistinguishable from low flows prior to harvest (Koppelar and Ziemer, 1990). Because an increase in low flows (i.e., more water in the stream) for summer months generally does not adversely affect the beneficial uses of the aquatic system, it will not be discussed any further. Small volumetric increases may provide improved habitat conditions (lower stream temperature, increased instream wetted area and volume) and survivability of aquatic species.

3.3.2.3 Peak Flows

Peak flow is the maximum instantaneous discharge measured in stream channels during high flow periods. Management activities can affect peak flows based upon their site specific effect, elevational location within a watershed and proportion of basin forest that has been altered by timber-related activities, such as roads and timber harvest.

Existing Hydrologic Conditions

WESTSIDE PEAK FLOWS

Western Washington (and much of eastern Washington) receives moderate to high precipitation and is influenced by rain-on-snow events. The significance of rain-on-snow events is the increase in water delivered to the stream system during these events compared to rainfall alone. When warm air and rain occur on areas with a snowpack, rapid melting of the snow can occur, resulting in a pulse of water into the drainage network. Rain-on-snow events can occur on mountain slopes in the transient snow zone which extends from altitudes of approximately 1,000 feet to 3,000 feet above sea level (Harr, 1986), but can shift upward or downward during any given storm due to varying meteorological conditions.

Peak flow events associated with rain-on-snow can be of greater magnitude than rain-only events because the rainfall is augmented by snowmelt. The direct effects of peak flows include stream channel alteration, bank erosion, redistribution of sediment and large organic debris, and flooding. In addition to the direct effect of peak flows, rain-on-snow events generate large inputs of water to the soils and can generate unstable conditions on hillslopes by increasing the pore-water pressure, which decreases the strength of the soil (Sidle et al., 1985); a reduction in soil strength increases the potential for slope failure.

EASTSIDE PEAK FLOWS

On the eastside, the buildup of snowpack over winter contributes to large amounts of spring runoff. Rain-on-snow events are less common. In forested areas east of the Cascades, snowmelt is the dominant mechanism for producing peak flows, most commonly in February to July depending upon location and elevation. Greater snowpack in forest openings in the eastside forest can result (Kattelman et al., 1983; Troendle, 1983). Peak flows are predominantly generated by snowmelt and may account for most of the 2- to 10-year flows. The timing of snowmelt runoff is important for many eastern Washington watersheds because this runoff is vital for irrigation supplies and fish habitat.

Management Influences on Peak Flows

ROADS

The design, construction, and maintenance of roads interact with watershed characteristics of soil topography, and geology and natural disturbances (such as large storms) to determine the effects that roads can alter the general hydrology of a particular watershed. The interception or storm routing of surface runoff and interception of subsurface flow by a road prism can affect the hydrology of a watershed. In a general sense, roads can act as extensions of the drainage network if the roads drain to streams. Road-influenced peak flows have been demonstrated in small drainages within watersheds (Ziemer and Lisle, 1977); however, the effects of roads on a river basin scale are more controversial (Jones and Grant, 1996; Beschta et al., 1997)

TIMBER HARVEST

The best understood effect of timber harvest is its influence on streamflow relating to altering snow accumulation and melt rate. Increased peak flows can occur in the winter, when a warm wet storm brings rain after a cold storm deposits significant amounts of snow. The snow melts much faster than from warming of the air temperature alone. Many floods in Washington, mostly on the west side of the Cascades, have occurred as a result of rain-on-snow events. While rain-on-snow events are a natural occurrence, their effects can be exacerbated when a watershed has been logged in a short amount of time (25 to 30 years) (Coffin and Harr, 1992; Troendle and Leaf, 1980). The two most important watershed variables that affect rain-on-snow events are elevation and extent of timber harvest.

Timber harvest has the potential to alter snow accumulation and melt rates in any portion of a watershed, but predominantly in the "rain-on-snow" zone. The rain-on-snow zone in western Washington typically occurs between 1,200 and 4,000 feet in elevation (Washington State Department of Natural Resources, 1997). Forest openings are conducive to increased snow pack accumulations because more snow reaches the ground since less tree canopy intercepts the snow from reaching the ground. Once a rainfall associated with a storm occurs, the forest openings are more conducive to higher rates of convection and condensation to the snow pack than the surrounding forest. The combination of greater snow accumulation and increased melt rates can lead to a greater rate of moisture available at the soil surface in forest openings during a rain-on-snow event than occurs in the adjacent forest (Coffin and Harr, 1992). The net result is that increased in runoff is expected from forest clearcuts in areas where rain-on-snow is prevalent.

Although not as well-understood, timber harvest may increase snowmelt peak flows (Benda et al, 1995). Because timber harvest can cause increased snow accumulation in openings, areas where runoff is dominated by snowmelt can theoretically experience increased peak flows. Existing research in the Pacific Northwest has not consistently demonstrated this effect, however. While Cheng (1989) found as much as a 35 percent increase in peak flows with 30 percent clearcuts in British Columbia, Fowler et al. (1987) found no effect in small watersheds in Oregon. In perhaps the most comprehensive study, Anderson and Hobba (1959) found an 11 percent increase in spring peak flows across 21 watersheds in eastern Oregon. This area is analogous to eastern Washington.

Rain-dominated watersheds, such as along the coast, may also be subject to increased peak flows, but due to different reasons. Studies that have shown peakflow increases in rain-dominated watersheds (Harr et al., 1975; Harr 1986) have correlated the increases with soil compaction, rather than timber harvest itself. Yet other studies indicate no change in peak flow after harvest. (Benda et al., 1995). If they occur, small basins seem to be more likely to experience effects than large basins.

3.3.2.4 History of Forest Practices Affecting Hydrology

The greatest conversion of timberlands to farms and towns occurred between 1850 and 1910. As timber harvest occurred and increased over time, different harvest methods such as splash dams, railroads, and then roads were used to access and transport timber. As a result of the transportation networks in forested environments and the harvest methods, increased erosion and watershed changes occurred. A very brief history of forest practices is described in Section 3.2.2.3.

Research completed within the past 20 years has clearly documented the link between forest practices and impacts on hydrology at the sub-basin scale (Megahan, 1972; Harr et al., 1975; Harr et al., 1979; Lisle, 1981; King and Tennyson, 1984; Hicks et al., 1991). For example, the influence of rain-on-snow events on downstream flooding has been well-documented and forest practices rules have been developed in response to this new understanding (Troendle and Leaf, 1981; Harr, 1986; Coffin and Harr, 1992).

Logging impacts to the hydrologic processes within a watershed include both direct and indirect effects. An example of indirect effects of forest practices on hydrologic processes is related to mass wasting. Timber harvest and road construction has been shown, in some cases, to increase rates of both surface and mass erosion and sediment delivery to streams. Increased sediment delivery can result in increased rates of aggradation throughout the stream network. One outcome of increased aggradation is to lower the flow threshold necessary to cause overbank flooding. Thus the flood frequency may be increased within a sub-basin.

Impacts on hydrology associated with the construction and use of logging roads include:

- increased fine sediment inputs to streams due to road-related surface erosion
- increased coarse sediment inputs to streams due to increased road-related mass wasting events
- increased peak flows at the sub-basin scale due to the creation of an extended drainage network and interception of subsurface flow
- change in timing of peak flows to interruption of natural subsurface flow rates increased flooding due to rain-on-snow events

Some examples of how forest practices rules address these impacts are listed below:

- requiring strict road maintenance and planning that reduces mass failures
- requiring higher standards of road construction which has lowered the number of road-related failures
- minimizing the size of allowable clearcut patch (120-240 acres)
- minimizing the total area within a watershed that can be hydrologically immature and timing of harvest patterns linked to understanding of rain-on-snow zones within watersheds

3.3.3 Environmental Effects

The environmental effects section addresses only peak flows, because the effects of changes in the forest practices rules on low flows and water yield are not considered to cause significant adverse effects on watershed resources and public safety.

3.3.3.1 Evaluation Criteria

Road Influence on Peak Flows

Although the results of studies are varied, there is a potential that road drainage may play some role in peak flow events, which would have greater impacts on first and second order drainages. This potential may be significant in certain basins or weather events, and will be evaluated based upon the road management and drainage criteria and potential for decrease (e.g., abandonment) in roads under each alternative.

Timber Harvest Influence on Peak Flows

Many studies have found a correlation between the hydrologic maturity of a basin, especially in the rain-on-snow elevation zone, and the potential for increased peak flows. The evaluation criteria for timber harvest-related peak flows is how well the forest practices rules under each alternative reduce the potential for large land areas in the rain-on-snow zone of a basin to become hydrologically immature (i.e., early seral stage). It is important to note that although the effect of rain-on-snow events is most pronounced in the rain-on-snow zone, the rain- and snow-dominated zones may also be affected, depending on storm temperature and preceding snow conditions. Therefore, the effects of timber harvest on peak flows in rain-dominated and snowmelt-dominated watersheds was also considered.

3.3.3.2 Alternative Evaluation

Timber Harvest Influence on Peak Flows

ALTERNATIVE 1

> Alternative 1 presents a moderate risk of effects on peak flows because they are only addressed through watershed analysis or DNR intervention.

The current forest practices rules address peak flows related to timber harvest by allowing conditioning of the size of clearcuts in the significant rain-on-snow zone of a watershed where peak flows have resulted in material damages to public resources. In addition, watershed analysis addresses peak flow issues, including areas where snowmelt is the dominant contributor to peak flows (e.g., Boise-Cascade, 1996). However, watershed analysis has only been applied to a small percentage of the state (see Appendix H, Watershed Analysis) and is voluntary for private landowners. Under Alternative 1, peak flow issues would be addressed in watersheds where watershed analysis is conducted.

ALTERNATIVE 2

> Alternative 2 would result in similar risk of effects on peak flows relative to Alternative 1 because land-owners would have less incentive to conduct watershed analyses, but road drainage would be improved.

Alternative 2 would result in a slight reduction in harvestable timber due to the RMZs, relative to Alternative 1. Also, watershed analysis would be required to the extent funding is available and voluntary for landowners. The rules under Alternative 2 also address peak flows related to timber harvest by allowing conditioning of clearcuts in the significant rain-on-snow zone of a watershed where peak flows have resulted in material damages to public resources. The effects of timber harvest on peak flows occur in watersheds with substantial area in the rain-on-snow elevation zones. The assessment of the watersheds would likely occur with watershed analysis. However, under Alternative 2, there may be less incentive to conduct watershed analysis since many components of watershed analysis have been incorporated into the new rules. If fewer watershed analyses are conducted, the potential impacts of timber harvest and road building on peak flows would receive less consideration. Therefore, the risk of timber-harvest related peak flows could be slightly higher than under Alternative 1.

ALTERNATIVE 3

> Alternative 3 would provide the lowest risk of harvest-related peak flow events because the rules would directly address the cumulative hydrologic maturity of the rain-on-snow zone.

Under Alternative 3, a new eastside hydrology module would be developed and applied to eastside watersheds that undergo watershed analysis. Watershed analysis would be required for all state lands and voluntary for private lands. In addition, a landscape rule would be applied to all applications to limit the amount of hydrologically immature (based upon crown closure) land within a watershed in rain-on-snow zones. The rule says that a minimum of two-thirds of lands by ownership, within the rain-on-snow zone of basins 1,000 acres or larger in size, must be maintained in stands that are at least 25 years old. This alternative would provide the greatest protection from potential management-related peak flows from rain-on-snow events.

Road Influence on Peak Flows

ALTERNATIVE 1

> Alternative 1 would not encourage reduction of road drainage from streams; therefore, there would be a moderate risk of road-influenced peak flow.

Under Alternative 1, the road drainage BMPs such as rolling grade dips, water bars, and grade dips at stream crossings are encouraged but not required (see Appendix F). Because

Alternative 1 does not require drainage structures that reduce the volume of surface water reaching streams, the implementation of these rules may have a greater effect in extending the drainage network and potentially influencing peak flows.

ALTERNATIVE 2

Alternative 2 would reduce the potential for road-related peak flow because road drainage to streams would be reduced and RMAPs would be implemented.

Under Alternative 2, closer spacing of ditch relief culverts would be required and outlets of ditch relief culverts would have to be located to allow the dispersal of water before reaching any stream. Road maintenance and abandonment plans would have to be implemented by 2015. These include abandonment of roads and the upgrade of all roads (except orphaned roads) to current construction standards, which includes drainage. The reduction in road surface drainage would reduce the potential of road influences on peak flows.

ALTERNATIVE 3

Alternative 3 would have similar or lower effects on road-related peak flows relative to Alternative 2.

Under Alternative 3, the effects of management on peak flows would be similar to Alternative 2. In addition, there would be no net increase in roads allowed for large landowners. However, road maintenance and abandonment plans would be implemented sooner (10 years) than Alternative 2. The reduction in roads and similar drainage guidelines as Alternative 2 would likely reduce the potential influence of roads on peak flows.

This page intentionally left blank